FOCUSED RESEARCH, Inc.
a New Focus company

November 14, 1994

Advanced Research Projects Agency
3701 North Fairfax Drive
Arlington, VA 22203-1714

Attention: Mr. Steven Fishman,
Program Manager

Subject: Contract N00014-94-C-0197
R&D Status Report

Dear Mr. Fishman:

Focused Research, Inc., is pleased to submit the R&D Status Report to the "Commercialize an Atomic Absorption System based on Frequency-Doubled Tunable Diode Lasers" contract.

If you have any questions, please contact me at (408) 734-1586 x140. We look forward to hearing from you.

Sincerely,

Marc D. Levenson,
Vice President

cc: Scientific Officer
Contracting Officer
Director, Naval Research Laboratory
Defense Technical Information Center
TACTEC

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R&D Status Report

ARPA Order No: 94-04 Program Code No: S0507A

Contractor: Focused Research Incorporated
1275 Reamwood Avenue
Sunnyvale, CA 94089-2256

Contract No: N00014-94-C-0197 Contract Amount: $399,977

Effective Date of Contract: 01 September 1994

Expiration Date of Contract: 31 May 1995

Principal Investigator: Dr. Marc D. Levenson

Telephone No: 408-734-8988

Short Title of Work: Commercialize an Atomic Absorption System based on Frequency-Doubled Tunable Diode Lasers for Rate Monitoring, Process Control and Spectroscopy of Physical Vapor Deposition

Description of progress:

The contracted program to develop an atomic abosrption vapor mointoring system began as scheduled on 9/1/94. Initial efforts focused on spectroscopic monitoring of low density yttrium vapor using a fundamental frequency laser. A test-bed system for frequency doubling was assembled. Parts were ordered for the construction of the prototype system. The progress for tasks 1 - 3, 5 - 6 and 8 are listed below:

Task 1 - Process development for domain inversion by means of titanium diffusion into the lithium niobate substrate is under way. To develop a source for monitoring titanium vapor density at 391.59 nm, we need to design and fabricate periodically poled lithium niobate waveguide chips with a finer domain grating than has yet been demonstrated. The first complete set of waveguide doubler masks has been obtained, and a new process for patterning titanium films without requiring lift-off has been demonstrated. The first diffusions have been made, with good results. Waveguides have also been patterned by proton diffusion. Evaluation of the first test doubler chips will begin as soon as the substrate has been diced, probably within days.

Task 2 - A temperature control system for the doubler has also been assembled and is undergoing tests. An optics test-bed set-up for evaluating the performance and tuning curves of the waveguide doubler chips has been assembled.

Task 3 - A high through-put optical isolator has been designed and is now being fabricated.

Task 5 - Customized mechanical parts for the ultimate "brass-board" have been designed and fabrication is beginning on prototypes. A high-power semiconductor diode gain element has been identified and ordered. Until the high-power laser contemplated for the final "brass-board" system is available, testing will proceed using an existing 15 mW laser.

Task 6 - Initial efforts focused on spectroscopic monitoring of low density yttrium vapor using fundamental frequency lasers and design of the first-generation frequency doubling chips for high density spectroscopy of titanium. A test-bed system for frequency doubling was assembled. Parts were ordered for the construction of the prototype system. In yttrium spectroscopy, the absorption of the most favorable line for non-doubled absorption monitoring was found to be of order 10^{-5} in a hollow cathode lamp. While this absorption could be detected by modulating the lamp discharge current, such a strategy was considered unfeasible for control of electron beam heated physical vapor deposition. Consequently, spectroscopic tools other than direct absorption are being explored, with FM spectroscopy at 450 MHz modulation frequency being the leading candidate at present. A signal to noise ratio of 30:1 was obtained for 10^{-4} absorption with a 100 Hz detection bandwidth. While concerns over sensitivity to potential detector misalignment in an actual deposition chamber have not been entirely put to rest, we are proceeding with an FM spectroscopy design for the low-density vapor monitoring part of this program.

Task 8 - Refurbishment of the "deposition test-bed" has begun with the installation of new viewing ports into the deposition region to allow optical access. Support systems for the optical components are being designed.

Change in key personnel:

Dr. Michael Bortz of Focused Research and Dr. Weizhi Wang of Stanford have joined the program. Dr. Bortz is an expert on periodically lithium niobate material and its processing, and Dr. Wang an experienced laser spectroscopist. Dr. Bortz is the scientist in charge of nonlinear source development. Dr. Weizhi Wang has joined the Stanford subcontract as post-doc in charge of spectroscopy development. Dr. Fejer remains a subcontractor under this program. Both Dr. Bortz and Dr. Wang will be an asset to the development of the project.

Special Events:

On September 29, the Focused Research / Stanford team attended a kick-off meeting at Lawrence Livermore National Laboratories sponsored by Dr. Thomas Anklam. At that meeting Dr. Shirley Gallanti described "specifications" for a titanium monitoring source that would be consistent with the performance of their present detection system. Those "specifications" were considerably more aggressive than those of the present contract. In particular, to accommodate the inefficiencies of the present beam-transport and detection apparatus, an output power at the second harmonic of 2 mW is desirable. In addition, the Livermore team has requested delivery of a prototype system in March 1995, two months before the anticipated delivery of the "brass-board" system at the end of this contract period.

The Focused Research / Stanford team will make an effort to approach the schedule and performance desired by Livermore. However, we do not believe that 2 mW of UV output is feasible on the current schedule, much less on an accelerated schedule. We have agreed to help Livermore improve its beam transport and detection efficiency and to do the initial doubled laser spectroscopy experiments at Livermore rather than Stanford. The UV source power target has been increased to 0.4 mW, on a "best-effort" basis.

W. Risk and Q. Chen of IBM have published a new method of electric-field periodic-poling KTP crystals which shows promise of increasing the efficiency of waveguide frequency doubling by a factor of 5, compared to titanium-diffusion-grating-poled lithium niobate. While this method has not yet been proved reproducible, the higher efficiency, improved stability and greater design flexibility obtained may make KTP doubling chips more desirable in the long-run. We are monitoring these developments in hopes that high efficiency material will become available in one year. This new technology will then replace crystals in the field.

Problems anticipated:
We do not anticipate a problem at this time. However, the Livermore group has requested increased performance and higher power. Additional semiconductor diode laser gain media were ordered from Spectra Diode Labs. The additional costs of $5,000 - $10,000 will depend on whether we achieve initial success in low-reflectivity facet treatment. To facilitate early delivery of a prototype source, we are re-scheduling the development of automated control and alignment systems to the end of the program. The Livermore group does not plan to tune the output wavelength over a wide range, but does plan to scan the laser back and forth continuously over the titanium absorption line. Simpler control electronics and algorithms may be adequate for such an application. To speed delivery to Livermore, the hollow cathode experiments contemplated for the frequency doubled system in task 7 will take place at Livermore, rather than Stanford. Task 11, in which a frequency doubled laser is used for spectroscopy of elements requiring blue light in a deposition test-bed will be dropped.

Actions Required by Government: None at this time.

Fiscal Status:
Amount currently provided on contract: $399,977.00

Expenditures and commitments to date:

Purchase Order	Amount	Descriptions
2FR2018	$4,250	# 4421 modulator-borrowed
2FR2015	$1,150	# 1601 1GHZ, visible Photodetector
2FR2013	$36.03	Connectors, thumbcap, switches
2FR1096	$1,160	Misc optical equipment
2FR1081	$2,950	#3321 high voltage amp
2FR1079	$719	AR "U" coat on Isolator
2FR1015	$570	TGG Rod 5MM x 20MM
2FR1021	$15,000	#6102 tunable diode laser
2FR2042	$250	PA1-1000 Prism Adjuster
Commitments Pending		
2FR2021	$21,260	#6224 780 nm laser
2FR2050	$185	AD22C-00-XO Temp Control Box
Labor for September, 1994	$3,772	
Labor for October, 1994	$2,271	
	$53,573	Material + Commitments + Labor only

Funds required to complete work:
At this time, we do not require additional funds to complete the project.

Marc D. Levenson　　11/11/94
Date